PATENT SPECIFICATION

(11) 1337 134

DRAWINGS ATTACHED

(21) Application No. 179/71 (22) Filed 1 Jan. 1971

(31) Convention Application No. 5759 (32) Filed 26 Jan. 1970 in

(33) United States of America (US)

(44) Complete Specification published 14 Nov. 1973

(51) International Classification H01J 61/12, 61/33

(52) Index at acceptance

H1D 11X 11Y 12B1 12B13Y 12B2 12B3 12B4 12B47Y 12B8 12C 18C 18D 35 5A 5H 9A 9B 9D 9Y

(19)

1 337 134

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(54) METAL HALIDE LAMP

(71) We, GENERAL ELECTRIC COMPANY, a corporation organized and existing under the laws of the State of New York, United States of America, of 1 River Road, Schenectady 12305, New York, United States of America, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to metallic vapor arc lamps using an arc discharge in mercury and metal halide vapors to produce light, and is more particularly concerned with control of the temperature pattern in the arc tube in order to obtain higher efficiency and better color.

The mercury arc lamp has a long life and reasonably good efficiency but relatively poor color rendition due to the bluish-green quality of its light. A radial improvement in both color rendition and efficiency may be achieved by adding to the mercury one or more vaporizable metal halides under proper control of loading, temperature and pressure, the preferred metal halide additive being sodium iodide, optionally with thallium iodide and indium iodide. Such lamps are described and claimed in U.S. patent 3,234,421—issued to Gilbert H. Reiling, on February 8, 1966, entitled "Metallic Halide Discharge Lamps". These improved lamps have been referred to as mercury metal halide lamps and more recently they have been termed simply metal halide lamps.

In its general construction and appearance, the metal halide lamp may resemble the conventional high pressure mercury vapor lamp comprising a high melting temperature glass arc tube mounted within a glass outer jacket. The more widespread type is single-ended and provided with a screw base at one end but double-ended lamps exist as also unjacketed lamps. Thermionic main electrodes are provided at the ends of the arc tube which contains a quantity of mercury and metal halides along with an inert gas for starting purposes. Thus, by way of example, one may add sodium iodide along with a lesser quantity of thallous iodide and indium iodide to the mercury to achieve a luminous efficiency in the range of 70 to 80 lumens per watt as against the 50 to 60 lumens per watt range of the ordinary mercury lamp. The lamp has the further advantage of an improved color containing a substantial percentage of red light and which is more pleasing to the eye.

The U.S. Reiling patent taught that the coldest portion of the arc tube of a metal halide lamp must always be hot enough during operation to insure that an effective amount of the metal halide is vaporized. This result is achieved by juxtaposing the arc tube wall sufficiently close to the arc so that the heat of the arc keeps the wall temperature at the required value. In practice one chooses an arc tube of the proper size having in mind the input wattage and the heat losses. For a given size or wattage, a metal halide lamp generally requires a shorter arc tube than a mercury lamp, and it is generally necessary to raise its temperature. In particular, the ends of the arc tube tend to run cool and their temperature needs to be raised. Various means have been proposed for increasing the arc tube temperature, for instance vacuum in the inter-envelope space instead of nonreactive gas, a transparent glass sleeve surrounding the arc tube, radiation reflective coatings on the ends of the arc tube, insulating caps over the ends of the arc tube, and shaping of the arc tube ends into small wells in which the electrodes are recessed.

The object of our invention is to increase the efficiency and improve the spectral output or color of mercury metal halide lamps.

By mapping arc tube surface temperatures, it has been found that the conventional techniques for raising the arc tube temperature reach their limit of effectiveness much sooner than necessary. The limit is reached when the hottest part of the arc tube begins to exceed the maximum temperature which the arc tube material can safely withstand. However

at such time all other portions of the arc tube are well below the limiting temperature. The arc tubes are commonly made of vitreous silica or quartz-like glasses for which 1070° is the upper limit because it is the strain point at which repeated heating and cooling result in fracture. In practice, the operating temperature must not be allowed to exceed 100°C if a reasonably long life is to be achieved.

The invention provides a high pressure electric discharge lamp intended for vertical operation comprising a generally cylindrical arc tube formed of a vitreous high temperature resistant material, a pair of arc supporting electrodes sealed into opposite ends of said tube, said tube containing a filling of mercury which is substantially completely vaporized under operating conditions, metal halides at least one of which is sodium iodide and an inert starting gas, said tube being of such size relative to the arc discharge maintained within it and the construction being asymmetric to reduce the temperature spread between the ends of the tube and to drive the temperature spread of the lower end substantially above 670°C and cause the coldest spot to be located above the lower end of the tube during operation without driving the temperature of the upper end above 1000°C in order to cause excess sodium iodide to condense on the tube wall above said lower electrode and reduce the segregation of sodium. The lamp contains excess liquid metal halide, that is more halide than can be completely vaporized under the operating conditions, and the excess tends to collect in the coldest region of the arc tube. The vapor pressure will correspond of course to the lower temperature of the cold spot. By reducing the temperature spread, the vapor pressure is increased without increasing the maximum temperature to which the arc tube is subjected.

In a vertically operated lamp, the lower end of the arc tube tends to run cold and the upper end tends to run hot. The temperature spread between the ends of the arc tube is reduced by means of an asymmetric construction such that more heat is generated at the lower end of the arc tube or less heat is lost from said lower end. One means consists of using a smaller electrode which runs hotter at the bottom and a larger electrode which runs cooler at the top. Other means for reducing temperature spread which may be used separately or cumulatively are a heat-reflective coating or a heat-insulating jacket about the lower end of the arc tube. Alternatively an end on the arc tube contoured for a higher temperature such as a tapered end or an end chamber reduced in size may be used. By such means, the temperature of the condensed metal iodides is raised and the condensate is driven away from the lower end and up the arc tube walls. This is found to reduce the segregation of the various metal species in the arc tube, the end result being higher efficiency and improved spectral output or color.

In the accompanying drawings:

FIG. 1 shows in side view a metal halide lamp embodying the invention.

FIGS 2*a* and *b* show arc tubes of prior lamps with the initial and terminal temperature distributions.

FIGS. 3*a* and *b* show initial and terminal temperature distributions in arc tubes embodying the invention and utilizing different sizes of electrodes at opposite ends.

FIGS. 4*a* and *b* similarly show the temperature distributions in arc tubes utilizing simultaneously different sizes of electrodes and asymmetric heat reflective coatings.

FIGS. 5*a* and *b* show the temperature distributions in smaller size arc tubes similar to those of FIGS. 4*a* and *b*.

FIGS. 6*a* and *b* show the temperature distributions in arc tubes embodying the invention and utilizing different sizes of electrodes and asymmetric end contours.

Referring to the drawing, a mercury metal halide vapor arc lamp 1 embodying the invention comprises an outer vitreous envelope or jacket 2 of ellipsoidal form and having a neck portion 3. The neck is closed by a re-entrant stem 4 having a press 5 through which extend relatively stiff inlead wires 6,7. These inleads are connected at their outer ends to the contacts of the usual screw type base 8, namely the threaded shell 9 and the insulated center contact 10 and at their inner ends to an inner envelope or arc tube 12*b*.

The inner arc tube 12*b* is made of quartz or fused silica and has sealed therein at opposite ends a pair of main arcing electrodes, 13 at the base end and 14*a* at the dome end, plus an auxiliary starting electrode 15 at the base end adjacent main electrode 13. The electrodes are supported on inleads which include intermediate thin molybdenum foil sections 16 hermetically sealed through the flattened ends 17, 18 of the arc tube, commonly referred to as full diameter pinch seals. The main electrodes 13, 14*a* each comprise a double layer tungsten wire helix wrapped around a tungsten core wire and are activated by thorium oxide which coats the turns and fills the interstices within the helix.

The arc tube is supported within the outer jacket by a divided or two-part mount. The upper mount section at the base end comprises a pair of longitudinally extending support rods 21 coming together at their upper ends to form an inverted "U" which is welded to inlead 6. Metal straps 22 fastened to the lower ends of the rods clamp about pinch seal 17, and right angle braces 23 engage blind notches in the end of the pinch seal to stiffen the assembly. The lower mount section at the dome end comprises longitudinally extending support rods 24 coming together at their lower

ends to form a "U" to which it attached a springy collar 25 engaging a re-entrant nipple 26 in the dome end of the outer envelope. The lower mount section engages pinch seal 18 through metal straps and right angle braces 28. Main electrode 13 is connected to inlead 6 through strap 29 and rod 21; main electrode 14*a* at the dome end of the arc tube is connected to inlead 7 through curving wire 31. Starting electrode 15 is connected to inlead 7 through current limiting resistor 32 having a value, for instance of 40,000 ohms. The inter-envelope space is evacuated in lamps of 400 watts size or smaller; in larger sizes such as 1000 watts, it is filled with inactive gas.

A terminal switch 33 consisting of a bimetal, that is a strip of dissimilar metals bent to a U-shape, is welded at one end to the inlead of main electrode 13. As the lamp warms up, the U-shaped piece opens out and its free end engages the inlead of starting electrode 15. The auxiliary electrode is thereby connected to the adjacent main electrode after starting and during operation of the lamp in accordance with the teachings of U.S. patent 3,226,597 — Green.

The arc tube contains an inert rare gas such as argon at a low pressure, for instance at 25 torr, in order to facilitate starting and warm-up. In addition the arc tube contains a fill or dose in the form of liquid droplets in which solid constituents consisting of metal halides may be contained during quiescent non-operating conditions. The quantity of mercury in the dose is such that upon the attainment of a stable operating condition, the mercury is substantially totally vaporized and exerts a partial pressure within the envelope in the range of 1 to 15 atmospheres, and it is adjusted to achieve the desired voltage drop at the rated operating current. It is necessary that no mercury remain in the pure liquid state since the operating temperature that is required to volatilize the metal halides is substantially higher than permitted by the foregoing mercury vapor pressure range when liquid mercury is present.

In a preferred embodiment, the other solid constituents comprise a quantity of sodium iodide in excess of that vaporized at the operating temperature plus smaller amounts of thallium iodide and indium iodide. Sodium contributes strong yellow-orange lines which are broadened into the red when the vapor pressure is sufficient, thallium produces an intense spectral line in the yellow-green at 5350 Å, and indium generates intense spectral lines in the blue at 4102 and 4511 Å resulting in a balanced color rendition suitable for general illumination. Proportions of constituents which have been found desirable fall within restricted ranges as follows:

	mg./cc.
Hg	2.0 —10
NaI	0.1 — 3.0
TlI	0.1 — 0.5
InI or GaI	0.01— 0.15

Prior to our invention, a so-called high dose had been favored. For instance in a 400-watt lamp operating with 135 volt arc drop and utilizing an arc tube 12 of 4.5 centimeters arc gap and about 20 cubic centimeters volume shown in Fig. 2, the filling consisted of Hg, 85 mg; NaI, 40 mg; TlI, 4 mg; and InI, 0.75 mg. The electrodes 13 and 14 designated H15) were both the same size and comprised a tungsten shank having a diameter of 30 mils and a double layer helix made of wire 20 mils in diameter and comprising about 9 turns in each layer. To insure sufficiently hot ends during operating, heat reflective coatings 35,36 consisting of zirconium oxide (indicated by speckling) were applied to the ends of the arc tube and adjacent portions of the pinch seals as per patent 3,374,377 — Cook, and the interenvelope space was evacuated. A typical temperature distribution upon vertical operation at the beginning of its life is mapped in FIG. 2a. The quartz is coolest (670°C) next to the lower electrode and hottest (780°C) next to the upper electrode, and is everywhere well below 1000°C.

The temperature of the arc tube rises with age. After it has operated an appreciable portion of its rated life, the envelope has darkened and a loss of sodium may have occurred. The darkening tends to make the arc tube run hotter and in addition the loss of sodium causes a voltage rise across the tube for a given current, which entails an increase in the input wattage tending to raise the temperature further. In FIG. 2b the temperature distribution over the same prior arc tube near the end of life has been mapped; the temperature of the quartz near the lower electrode is now 800°C which is not excessive but the temperature in the vicinity of the upper electrode is now 1020°C. The high temperature at the upper electrode is close to the softening point of quartz and indirectly sets the limit on the lamp's performance because the temperature of 670°C at the lower electrode at the beginning of life is dictated by it and is too low for good color and high efficiency.

Turning now to a preferred embodiment of the invention, we prefer to use a somewhat shorter arc tube 12*a* having an arc gap of about 4.0 centimeters and a volume of about 18 cubic centimeters. Also a so-called low dose is used consisting of Hg, 90 mg; NaI, 16 mg; TlI, 0.9 mg; and InI, 0.16 mg. To reduce the temperature spread between the

lower and upper ends of the arc tube, an asymmetrical construction wherein a smaller electrode 14*a* is provided at the lower end and a larger electrode 13 at the upper end may be used as illustrated in FIGS. 3*a* and 3*b*. Under similar conditions of voltage, current, and input watts, a smaller electrode will run hotter and raise the temperature of the tube in its immediate vicinity. Since in a vertically operating lamp convection effects naturally tend to make the lower end run cooler, the use of a smaller electrode at the lower end tends to equalize the temperatures throughout the tube and reduce the temperature spread from end to end. By way of example, an HI5 size electrode is used for the upper electrode 13 and a smaller size electrode designated H14 is used for the lower electrode 14*a* wherein the shank diameter is 22 mils, the wire size in the helix is 14 mils on the inner layer and 17 mils on the outer layer and about 8 turns are wound in each layer to form the helix. The temperature distributions at the beginning and near the end of life are shown in FIGS. 3*a* and 3*b*, respectively. The minimum temperature occuring in the vicinity of the lower electrode at the beginning of life has been increased to 735°C and this results in a higher metal halide vapor pressure entailing higher efficiency and improved color. The maximum temperature occurs in the vicinity of the upper electrode near the end of life and is 950°C which is well below the upper limit of 1070°C for fused silica.

The temperature spread between the ends of the arc tube may also be reduced by applying heat reflective coatings asymmetrically to the two ends. For instance the zirconium oxide coating may be removed entirely from the upper end and extended higher at the lower end. In the preferred embodiments of the invention illustrated in FIGS. 1, 4 and 5, the features of different sizes of electrodes and asymmetrical heat reflective coatings have been combined. In FIGS. 1 and 4 corresponding to a 400 watt size lamp, the upper electrode 13 in arc tube 12*b* is of the larger H15 size while the lower electrode 14*a* is of the smaller H14 size. In FIGS. 5*a* and *b* corresponding to a 175 watt size lamp, the upper electrode 13*a* in arc tube 12*c* is of the H14 size while the lower electrode 14*b* is of a yet smaller size wherein the shank diameter is 18 mils and the wire size is reduced proportionately. A heat reflective zirconium oxide coating 36*a* has been applied to the lower end of the arc tubes only and it extends up the arc tube walls to about 15 mm. from the midpoint of the tube in FIG. 4. The temperature distributions at the beginning and near the end of life are shown in FIGS. 4*a* and 4*b*, and 5*a* and 5*b*, respectively. The minimum temperature in the vicinity of the lower electrode at the beginning of life has now been raised to 750°C for the 400 watt lamp and 780°C for the 175 watt lamp. The maximum temperature in the vicinity of the upper electrode near the end of life is 930°C in both cases and safely below the upper limit for quartz.

The temperatures mapped on FIGS. 4*a* and 5*a* indicate a substantially uniform temperature over the arc tubes at the beginning of life and this is a desirable condition. Near the end of life, FIG. 4*b* and 5*b* indicate a spread of merely 35° to 40° between the ends and this represents a very substantial improvement over the prior lamp represented by FIG. 2*b*. Table 1 below gives the results from the point of view of lumens output, efficiency and percent red in the spectral output as between a prior lamp such as shown in FIG. 2, the lamp of FIG. 3 utilizing asymmetrical electrodes and symmetrical reflective coatings, and the preferred lamp of FIG. 4 using asymmetrical electrodes and asymmetrical reflective coatings.

TABLE 1

MV400 (0 Hour Performance, Vertical Operation)

	Fig. 2 Design	Fig. 3 Design	Fig. 4 Design
Electrode size	Symmetrical	Non-symmetrical	Non-symmettical
Reflective Coating	Symmetrical	Symmetrical	Non-symmetrical
Output: Lumens	30,000	35,000	40,000
Efficacy: Lumens per watt	75	88	100
% Red	2.8	5.5	6.5

It will be observed that in the FIG. 4 design which constitutes the preferred embodiment of the invention also illustrated in FIG. 1, the efficiency has been raised from 75 lumens per watt to 100 lumens per watt and the percent red has been increased from 2.8 to 6.5.

Another way of equalizing the temperatures of the ends of the arc tube consists in altering shape or contour of the arc tube ends. FIG. 6 illustrates an arc tube 12*d* for a 400 watt size lamp in which the pinch seal at the lower end forms a tapered or cone-shaped closure 37 while the upper end is conventionally hemi-pherically shaped. It is not necessary to use a cone shape; and configuration which reduces the heat loss may be substituted, for instance a well or reduced diameter end chamber at the lower end. The feature of asymmetrically shaped ends may be combined with differently sized electrodes 13 and 14*a* and a heat reflective coating 36*a* on the lower end only as illustrated to achieve substantial equalization of temperature at the ends of the arc tube in vertical operation. Average temperatures measured on various lamps are mapped on FIG. 6*a* for the beginning of life and FIG. 6*b* for the end of life.

The lamp illustrated in FIG. 1 is intended for base up vertical operation; by reversing the arc tube end for end relative to the outer envelope, a base down design results. Vertical operation ordinarily includes departures from vertical of as much as 15°. With the present lamp, benefits in efficiency and color rendition are obtained with departures from vertical as great as 45° but the maximum terminal temperature may exceed desirable limits for long life. Such departures are comprehended when the lamp is said to be intended for vertical operation.

The effect of raising the temperature at the lower end of a vertical arc tube goes beyond simply increasing the temperature of the halide pool. The ordinary effect of increasing the pool temperature is, of course, to increase the vapor pressures of the metal iodides and this results in increased lumens and a warmer color, that is more red. However as the cold spot is moved higher up the arc tube wall, another effect takes place and this is a reduction in alkali metal segregation which occurs in a vertically burning lamp. The asymmetrical designs of the invention contribute to the relocation of the cold spot upwardly from the lower end of the arc tube and thereby reduce the segregation of the various species resulting in improved color and more uniform color from end to end of the arc tube.

WHAT WE CLAIM IS:—

1. A high pressure electric discharge lamp intended for vertical operation comprising a generally cylindrical arc tube formed of a vitreous high temperature resistant material, a pair of arc supporting electrodes sealed into opposite ends of said tube, said tube containing a filling of mercury which is substantially completely vaporized under operating conditions, metal halides at least one of which is sodium iodide and an inert starting gas, said tube being of such size relative to the arc discharge maintained within it and the construction being asymmetric to reduce the temperature spread between the ends of the tube and to drive the temperature of the lower end substantially above 670°C and cause the coldest spot to be located above the lower end of the tube during operation without driving the temperature of the upper end above 1000°C in order to cause excess sodium iodide to condense on the tube wall above said lower electrode and reduce the segregation of sodium.

2. A lamp as claimed in Claim 1, wherein a smaller size of electrode is used at the lower end to produce more heat.

3. A lamp as claimed in Claim 1 or Claim 2, wherein a more extensive heat reflective coating is applied at the lower end than at the upper end.

4. A lamp as claimed in Claim 3, wherein a heat reflective coating is applied to the lower end only.

5. A lamp as claimed in Claim 4, wherein the heat reflective coating extends beyond the upper end of the lower electrode.

6. A lamp as claimed in any of the preceding Claims, wherein said asymmetric construction comprises a tube end configuration reducing heat loss at the lower end.

7. A lamp as claimed in any of the preceding Claims, wherein the metal halides also include thallium iodide and indium iodide.

8. A lamp as claimed in any of the preceding Claims, wherein the arc tube material is fused silica.

9. A high pressure electric discharge lamp intended for vertical operation substantially as hereinbefore described with reference to the accompanying drawings (except Figures 2*a* and 2b).

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Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1973.
Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

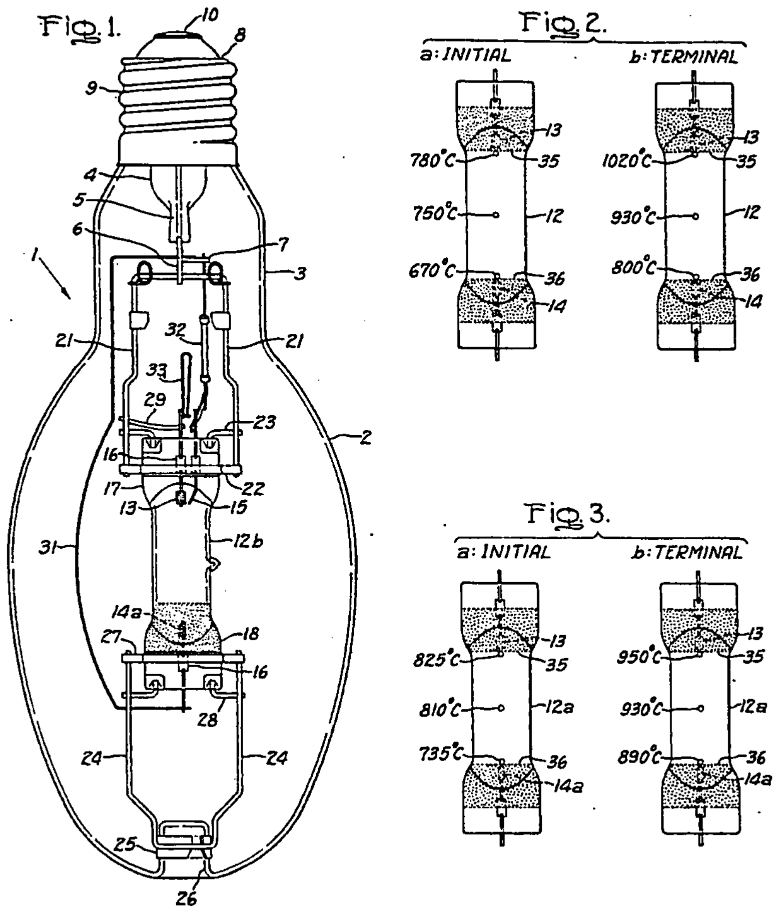
Fig. 1.
Fig. 2.
a: INITIAL
b: TERMINAL
780°C
750°C
670°C
1020°C
930°C
800°C
Fig. 3.
a: INITIAL
b: TERMINAL
825°C
810°C
735°C
950°C
930°C
890°C

Fig. 4.

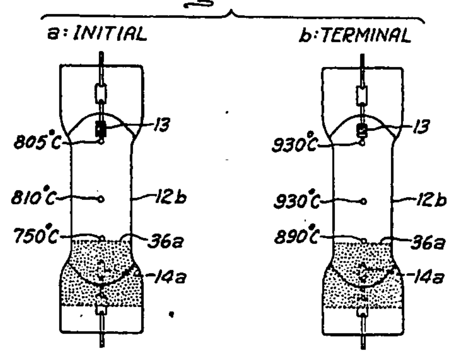

Fig. 6a. (INITIAL)

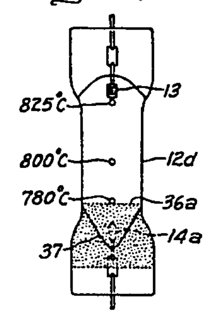

Fig. 5.

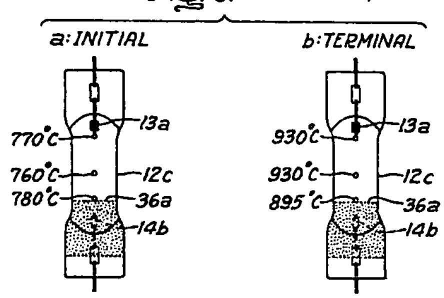

Fig. 6b. (TERMINAL)